# Chapter 8
# General Considerations

## 8-1. Background

The earliest rockfill dams in the U.S. were built in the southwest and west just before the turn of the century (Wegmann 1899). Most were of loosely dumped quarried rock with some version of core or upstream facing including wooden planking, concrete, or hand-placed rock dry-wall. From thence up until the 1950's, the design and construction of rockfill dams were a matter of empiricism. Construction was by end-dumping over high slopes with water sluicing in 18- to 61- m (60- to 200-ft) lifts. The sluicing with water jets was intended to displace fines from between the larger particles to produce rock-to-rock contact among the larger particles and reduce the compressibility of the mass. However, the technique still produced rockfill which was relatively compressible and subject to considerable post-construction volume change. The transition to compacted rockfill for both earth-core and concrete-face dams occurred during the period 1955-1965 (Cooke 1984) as shown in Figure 8-1 (Cooke 1990). This transition was possible because of the advent of heavy vibratory rollers and was particularly spurred by Terzaghi's criticism of dumped rockfill for its excessive compressibility and his recommendation of compacted rockfill in thin lifts as a means of greatly reducing it and also allowing the use of poorer quality rock (Cooke 1960). In the United States, the 136-m-high (445-ft), Corps of Engineers Cougar Dam (completed in 1964) was the first major earth and rockfill structure in which vibratory rollers were used to compact the rock shells (Bertram 1973). At the time of the construction of Cougar Dam there existed practically no information about the construction and evaluation of compacted rockfill so that trial and error test-fill procedures were used as the work progressed. It is interesting to note that Terzaghi had stated earlier that it would be impossible to determine the properties of rockfill in the laboratory and that only experimental fills should be used for such purposes. Even the most recent literature (NATO 1991), though filled with laboratory and model study information on rockfill properties and behavior, still confirms a continued reliance on test fills. Notwithstanding that statement, it can also be said that, in overview of the significant experience gained and common current practices concerning rockfill, test fills may sometimes be in wider use than actually necessary. In the remaining portion of this Part of the manual, test fill will be spoken of in the singular but it is not at all uncommon that more than one test fill may be needed. The reader should have no difficulty in recognizing the aspects of that to follow which may dictate more than one fill.

## 8-2. Why a Test Fill?

The main properties of interest of compacted rockfill fall under or relate to, shear strength, compressibility, permeability, and suitability of compaction equipment. Because of the fundamental nature of rockfill being cohesionless and containing large particles, it is not feasible, nor is it possible to obtain or test large "undisturbed" samples to determine the pertinent properties. Furthermore, the typical three-dimensional heterogeneity of rockfill and the densities typically obtained from field compaction cannot be replicated in reconstituted laboratory specimens in those limited cases where very large laboratory testing equipment of high load capacity is available. Laboratory studies of rockfill properties have been conducted on gradations containing smaller maximum particle sizes than most often actually placed and have, therefore, been more akin to parameter studies to provide insights on effects of variations in those parameters and to provide educated estimates of full-scale gradation behavior. In specific case histories, such data can be applied in numerical analyses coupled with observed embankment behavior to assess the quality of the laboratory results for predictive purposes but the state of that art should probably be considered to be in a state of relative infancy. Even the more frequently performed versions of maximum density tests have usually involved altered gradations (scalped) or modelled gradations (scalped/replaced or parallel) with significantly smaller maximum particle sizes. The profession has not thoroughly established the effects of such practices on the numbers yielded in comparison with full-scale materials. Test fills have then often been the basis for determining traits of the compacted rock which have led to completely satisfactory dam embankments including the very highest yet constructed. If the rock is of high compressive strength (sound rock), test fills may not even be necessary or adequate placement and compaction procedures can be determined in the early stage of construction without elaborate test fill operations. In this case, the only tests needed are drill core samples and saturated unconfined compressive tests which are among those previously mentioned in Part 1. Cooke further states that for sound rock, four passes of a 9.1-Mg (10-ton) vibratory roller upon layer thicknesses averaging about 1 m (3.3 ft) have become standard practices. Heavier rollers have not been found to usually offer any advantages. Since permissible maximum particle size for sound rock can be equal to the lift thickness if the proper placement method is used (to be discussed later), the most efficient

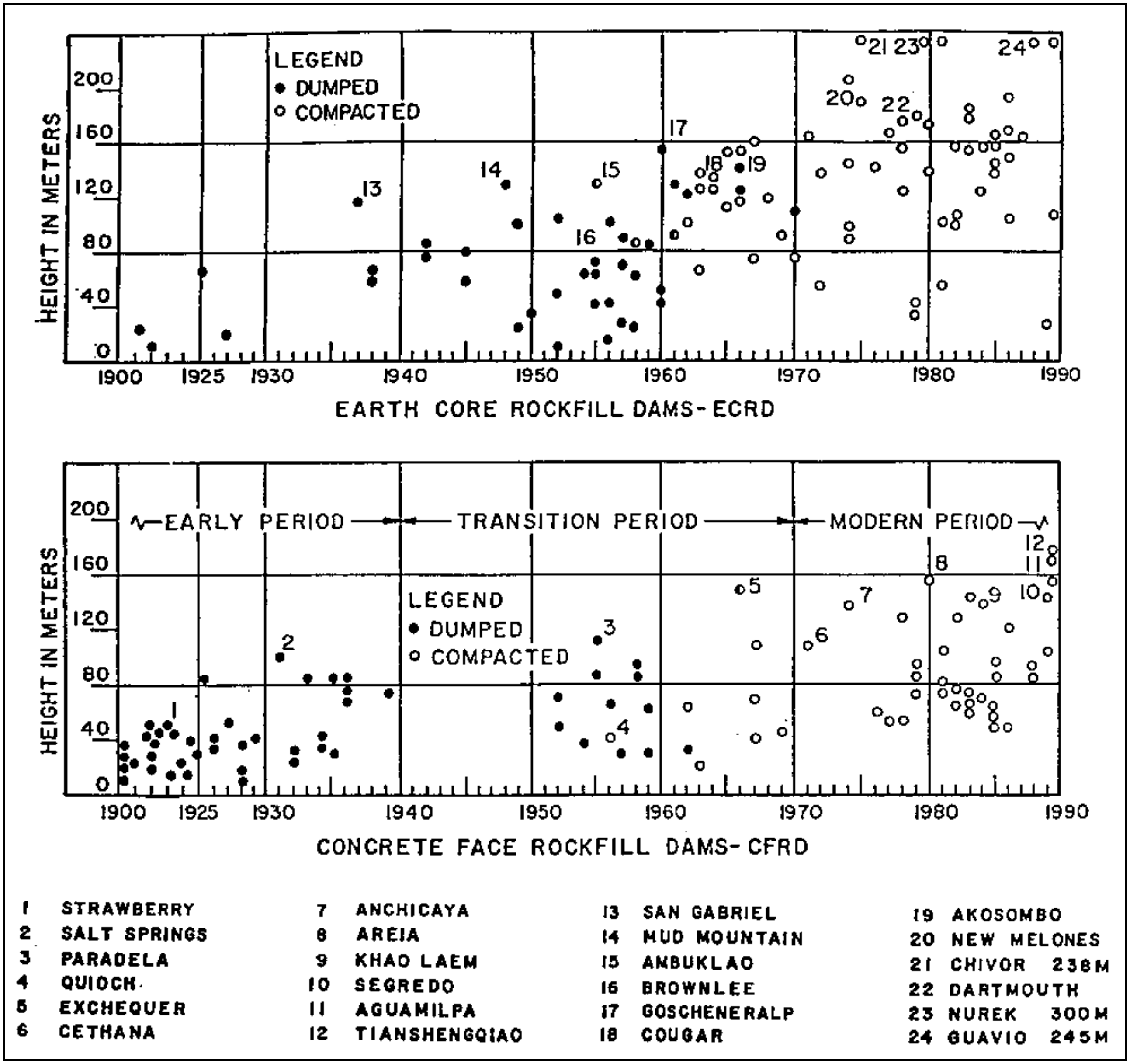


**Figure 8-1. Transition in practice from dumped rockfill to compacted rockfill (after Cooke 1990)**

quarrying operations determined from the test quarry may essentially dictate the lift thickness. If the available rock material is of low compressive strength (say, less than $55 \times 10^6$ Pa or 8000 psi), a test fill program is typically necessary. It has been previously stated in Part 1 that for softer rock types or conditions, degradation of the material from the quarry through all aspects of its handling including loading, processing (if employed), hauling, stockpiling (if employed), placement, and compaction (whatever the combinations of lift and equipment) cannot be confidently predicted by even the most experienced individuals much less the best placement/compaction procedures. Indeed, the question sometimes exists as to whether the material will ultimately be a free-draining rockfill after compaction or whether it will have degraded or must be made to degrade (because it will do so eventually postconstruction) into a soil material and treated as such in all aspects of design, construction, and construction control. An example of material which may appear to be a rock upon quarrying but will deteriorate into a soil upon wetting (whether stockpiled or compacted in the embankment) with time are certain shales (Lutton 1977). In planning and conducting a test fill program, it should be kept in mind that it can also offer considerable advantages in optimizing design and providing project construction personnel with the opportunity to familiarize themselves with materials and construction procedures.

## 8-3. Representative Procedures

A most important consideration for any test fill program is that procedures employed in constructing the test fill must simulate, as closely as possible, feasible construction procedures to be used in the project fill. The achievement of this imperative objective requires some experience in the construction of rockfill. If test-fill procedures do not closely simulate actual construction, the value of the test-fill investment is compromised and the effort may even do more harm than good. If experience in rockfill construction and its sampling/testing is seriously lacking, the use of a test fill as a preconstruction training exercise for project personnel may be a justified investment for sound rock and a natural advantage of test fill programs usually required for softer materials.

## 8-4. Test-Fill Scheduling

It has been by far the greatest preference to conduct test fills before construction begins (i.e., at some time during the project design stage) but there have also been cases of provisions made in the bid documents to allow for their construction during the early phases of actual construction. If the latter approach is under serious consideration, it must be based on very substantial confidence that the items to be determined from the test fill have no potential of altering the design of the embankment or of rejecting the basic adequacy of the available materials. On the other hand, the advantages of a prebid test fill include: results can be used by the designer to prepare specifications for rock placement and compaction (and blasting/processing if a test quarry is also conducted), the quarry face can be inspected by prospective bidders, and construction personnel can be trained for adequate visual observation skills and required testing procedures. Therefore, a properly conducted prebid test fill program will most likely result in a lower bid. A prebid fill would naturally be scheduled to start at a point in the iterative-step development of the test quarry such that gradations produced in the test quarry and available for the test fill construction are deemed to be those recommended for project construction. The decision of when to conduct a test fill, then, is one which must be based on features of the individual project.

## 8-5. Flexibility

A test fill program must be flexible. Because of natural rock variations and unpredictable behavioral characteristics, it is often impossible to lay out a definite program in advance from which there will be no deviations. Procedures and envisioned specifications have often been altered based on results of completed portions of an original program. The test fill program designers must anticipate that possibility.